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"Up Against the Wall" – Solid and Liquid Solutions to Fusion's Materials Challenges

Novel materials have important implications for power handling and performance

DENVER, Colorado, Oct. 24, 2005 – Experiments at the Massachusetts Institute of Technology and Princeton University have demonstrated novel approaches to designing effective containment walls for fusion reactors. The new methods, coating wall materials with an ultra-thin layer of boron and using liquid metal as a wall material, have important implications for the design of fusion reactors.

The selection and qualification of wall materials is a key issue in the development of fusion as a practical energy source. Such surfaces, like the tiles on a space shuttle, must endure extremely high heat loads. In addition, they must stay structurally sound in a nuclear environment, resist erosion, and not soak up tritium, the expensive fuel that would be used by fusion reactors. The proper choice of materials could also dramatically reduce the time period over which a reactor would remain radioactive.

In experiments at M.I.T. with the Alcator C-Mod tokamak, a chamber that uses strong magnetic fields to confine plasma, researchers used a molybdenum wall with and without a thin boron coating. Results from C-Mod are particularly relevant because its conditions are close to those of a fusion reactor in important ways, including wall power density, plasma density and pressure, and magnetic field.

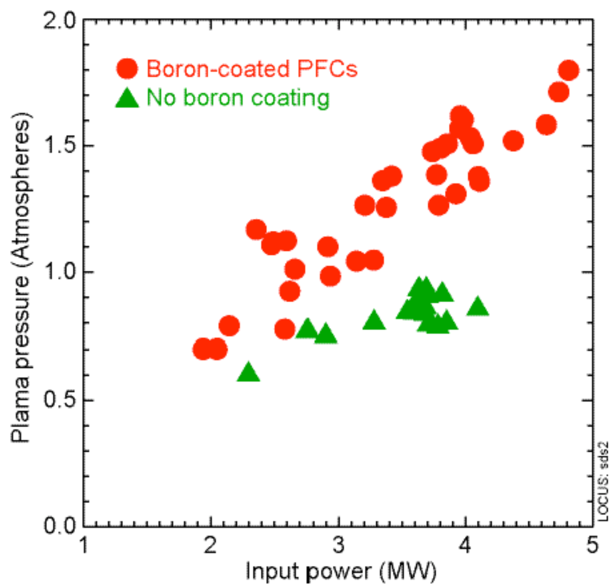

Fig. 1: Record plasma pressures close to that of the ITER reactor design were achieved with a thin boron coating on wall surfaces.

Coating the molybdenum surfaces with a thin boron layer (0.1 millionth of a meter thick) led to a world-record volume-average tokamak plasma pressure of 1.8 atmospheres, close to that of the International Thermonuclear Experimental Reactor (2.8 atmospheres, see Figure 1). This record was achieved under reactor-like conditions.

In comparison, bare molybdenum (Mo)walls lead to poorer energy confinement (see Figure 1); additional power must be used to heat the plasma to the same hot temperatures (pressures). The degradation is due to eroded molybdenum atoms entering the hot core plasma, leading to radiation cooling. Molybdenum levels in the core plasma were higher by a factor of 10 than when surfaces were coated. These experiments indicate that operation with a thin boron wall coating enhances material performance.

A radical alternative to solid surfaces is to use a liquid for a reactor wall. For the first time, experiments on the Lithium Tokamak Experiment (LTX) at the U.S. Department of Energy's Princeton Plasma Physics Laboratory have demonstrated that a liquid metal can withstand the heat loads expected in fusion reactors.

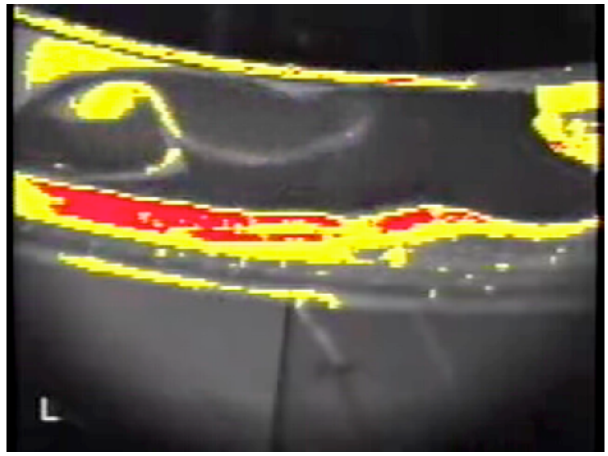

Fig. 2. Infrared image of liquid lithium in the tray that encircles the bottom of the LTX device. The swirling pattern that indicates the circulation of the liquid lithium is clearly evident. The electron beam hits the lithium immediately to the left of the picture.

The primary mission of LTX is to study the interaction of plasmas with lithium, a candidate material for a fusion reactor first wall. Initial LTX experiments showed that lithium absorbs impurity elements that can cool the plasma. It also reacted with the hydrogen fuel at the edge of the plasma. This prevented the undesirable build-up at the plasma boundary of the cool gas that "recycles" back from a conventional, solid first wall.

When subjected to heat loads greater than those expected in a fusion reactor, the lithium liquefied and began to swirl rapidly, distributing the heat in much in the same way stirring makes all of the soup in a pot reach the same temperature (see Figure 2). The "self-stirring" of the lithium observed in the LTX experiments suggests a simple and efficient technique for heat dissipation without the use of expensive pumps and complex plumbing. It is a new concept that has potential to solve the heat load challenge in fusion reactors and other high heat load environments, like "dumps" for high intensity beams.

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[FI1.00003] Operation of Alcator C-Mod with high-Z plasma facing components and implications
Abstract: **http://meetings.aps.org/Meeting/DPP05/Event/34914**
October 25, 2005
Tuesday, 10:30–11:00 am

Invited Session FI1: The Road to Burning Plasmas
Adam's Mark Hotel - Plaza Ballroom ABC

[RP1.00048] Progress on the Lithium Tokamak Experiment
Abstract: **http://meetings.aps.org/Meeting/DPP05/Event/36070**
October 27, 2005
Thursday, 2:00 pm
Session RP1: Poster Session VIII
Adam's Mark Hotel - Grand Ballroom I & II